Table of Contents

E90 Dynamic Driving Systems

Initial Print Date: 03/05 Revision Date: 06/05

Dynamic Driving Systems

Model: E90

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Establish an understanding of the changes in the DSC system

Dynamic Stability Control System

The E90 in the U.S. is equipped with a new Dynamic Stability Control System (DSC) referred to as MK60E5, manufactured by Continental Teves, which builds upon the systems used in other BMW models. With this system several new functions are introduced that result in significantly improved comfort during brake intervention (due to utilization of a PWM signal on the input control valves) and more precise wheel braking.

New functions introduced with MK60E5:

- Fading Support
- Braking Readiness
- Brake Disk drying
- Soft Stop
- Start Assist
- Electronic Control Brake Actuation (ECBA)
- Yaw Moment Compensation with AFS

These new functions contribute to increased directional stability, optimized comfort, enhanced system availability/response plus reduce the minimum braking distance.

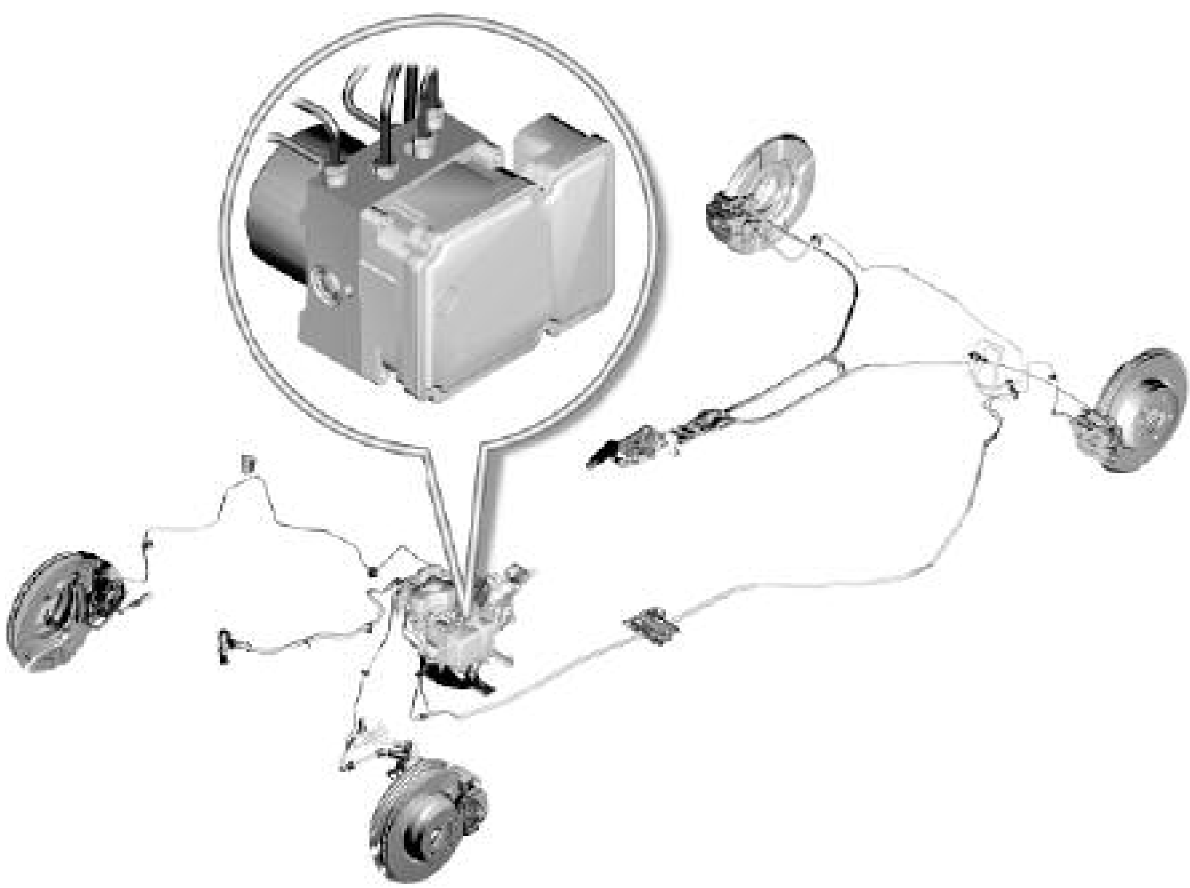
In the MK60E5 the designation "E5" represents the 5 pressure sensors which are integrated into the hydraulic control unit:

- A combined pressure sensor on the inlet side which monitors the plausibility of the pressures of the tandem brake master cylinder (THZ)
- Four further sensors on the outlet side which measure the braking pressure of the assigned wheel brake

Note: That the labeling of the DSC button has been changed to DTC and the MK60E5 system will also be used on the New M5.

The new functions available on the MK60E5 DSC system are a result of the following additional components:

- Solenoid valves with variable map for flow rate - utilizes a PWM signal
- 5 brake pressure sensors integrated in the new DSC module
- 4 active wheel-speed sensors with direction of rotation detection
- 1 longitudinal-acceleration sensor on the circuit board of the DSC control module
- DSC sensor taken with redundant signals on vehicles with Active Steering (2x rate of yaw, 2x lateral acceleration)



Fading Support

High temperatures (>550°C) can occur at the brake discs when brakes are applied over a long period (i.e. brakes applied while traveling downhill) or as a result of multiple "extreme" brake applications (i.e. applied pressure >80 bar). As the temperature of the brake disc increases, the level of friction that can be generated when the brake pads are applied is decreased (coefficient of friction is reduced as brake disc temperature increases), which can result in a diminishing brake effect (fading).

In order to reduce the brake "fading" effect the DSC system (MK60E5) calculates the temperature of the brake discs, based on:

- Applied brake pressure
- Duration of brake application
- Rate of vehicle deceleration

In the event the DSC system detects fading, brake pressure is increased in line with the calculated temperature model in order to maintain a constant ratio of brake pedal force to vehicle deceleration (if necessary, pedal travel is increased to compensate for the fading effect).

The DSC system detects fading as follows:

- DSC compares the current vehicle deceleration with a nominal value based on the current brake pressure.
- DSC increases brake pressure until the nominal deceleration is achieved or until all wheels are subject to ABS control.
- Process is ended when the brake pedal is released.

Note: The increase in brake pressure depends on road speed (under 100 km/h).

At the time this function is activated, a Check-Control message (brake warning light) appears in the LCD display in the instrument cluster (warning threshold 1). If the brake-disc temperature increases further, the legally stipulated brake warning lamp is also activated (warning threshold 2).

Braking Readiness

If the DSC system notices that the accelerator pedal is released quickly, the brakes are immediately pretensioned, to shorten the brake apply response time. To accomplish this task the DSC system generates a low braking pressure by applying a PWM signal to the solenoid valves, without creating any measurable deceleration of the vehicle. By applying a small amount of brake pressure the working clearance between the brake pads and brake disc is reduced. If the brakes are not applied within a certain time, the brake pressure that was applied is reduced.

The pre-tensioning of the brakes depends on the vehicle's speed (above 70 km/h).

The Brake Readiness function is activated under the following conditions:

- Vehicle speed > 70 km/h
- Minimum time between rapid accelerator pedal release and brake application < 8 sec. (DME provides the signal regarding rapid release of accelerator pedal to DSC via PT-CAN)

Brake Disk Drying

Brake disk drying removes moisture that gathers on the brake disks while traveling on wet roads or in the rain.

In order to dry the brakes while the vehicle is traveling down the road, the DSC module generates a low brake pressure which ‘lightly” applies the brakes disks and “wipes down” the disks without creating a measurable deceleration of the vehicle.

The application of the low brake pressure signal is done on a cyclical (regular) basis and is dependent on:

- Road speed (greater than 70 km/h
- Signal from rain sensor indicating continuous wiper operation (e.g. stage 1 or 2)

The drying action cycle is performed approximately every:

- 200 sec during stage 1 operation
- 120 sec during stage 2 operation

Note: The cycle is altered if the brakes are applied by the driver during these times.

This function results in a shorter response time if the brakes are applied during the cyclical low brake pressure application.

Soft Stop

Soft stop prevents a “jerky” stop causing the occupants to "lurch" forward, when braking the vehicle to a standstill.

Activation of function:

- Light brake application (<25 bar) under constant pressure
- Road speed (under 5 km/h)

The soft stop function reduces the braking pressure at the rear axle just prior to the vehicle reaching a complete stop in order to reduce “jerking/jolt” effect normally encountered when reaching a standstill. The DSC system calculates the moment that standstill can be expected based on the current road speed plus rate of deceleration and reduces braking pressure accordingly.

Start Assist

The start-off assistant prevents the vehicle from moving unexpectedly, based on the degree of incline, as the driver releases the brake pedal and moves to the accelerator pedal (ie. when pulling away on a hill).

The “start assist” function is accomplished as follows:

- Gradient (degree of incline) is determined by the longitudinal-acceleration sensor located in the DSC control module.
- Based on the degree of incline, the necessary braking torque or engine torque is calculated by the DSC module.
- Brake pressure needed to hold the vehicle is momentarily maintained (approx 2 sec).
- Brake pressure is reduced as soon as the available engine torque is sufficient to move the vehicle or accelerator is not depressed within approx. 2 sec.

The function can be activated when driving forward or backwards and is deactivated when the parking brake is applied and can not be activated if the transmission is in neutral.

Note: If no move is made to pull away within approx. 2 seconds of the brake pedal being released, the start-off assistant will be deactivated.

Electronic Control Brake (ECB) Actuation Interface

The interface between Dynamic Stability Control (DSC) and Active Cruise Control (ACC) has been improved with the introduction of the Longitudinal Dynamic Management (LDM) system, which is responsible for the transmission of the signals associated with ACC/cruise control operation.

The software in the DSC control module has been enhanced and allows the demands of the ACC to be evaluated more quickly thereby allowing pressure at the brakes to be built up or reduced more efficiently with regard to vehicle deceleration and comfort.

Yaw Moment Compensation

With conventional systems, the driver has to actively steer the vehicle in a straight line if the brakes are applied on a road surface with non-uniform traction levels ("split μ"). In this situation counter steering keeps the vehicle in its track and helps to achieve acceptable braking distances.

On the E90, if the vehicle is equipped with the Active Front Steering (AFS) option and brakes are applied on a road surface with non-uniform traction levels ("split μ"), DSC in conjunction with AFS, initiates the active steering actions in order to stabilize the vehicle and shorten the braking distance. The function is accomplished by having the DSC control module calculate the yaw rate plus interpret information from the front steering angle sensor and transmit the information to the AFS control module, which establishes the yaw-moment compensation correction angle needed for stabilization/counter steering.

System Components

The DSC system consists of the following:

Inlet & Distribution Valves

These solenoid valves used to be digitally actuated: either OPEN or CLOSED.

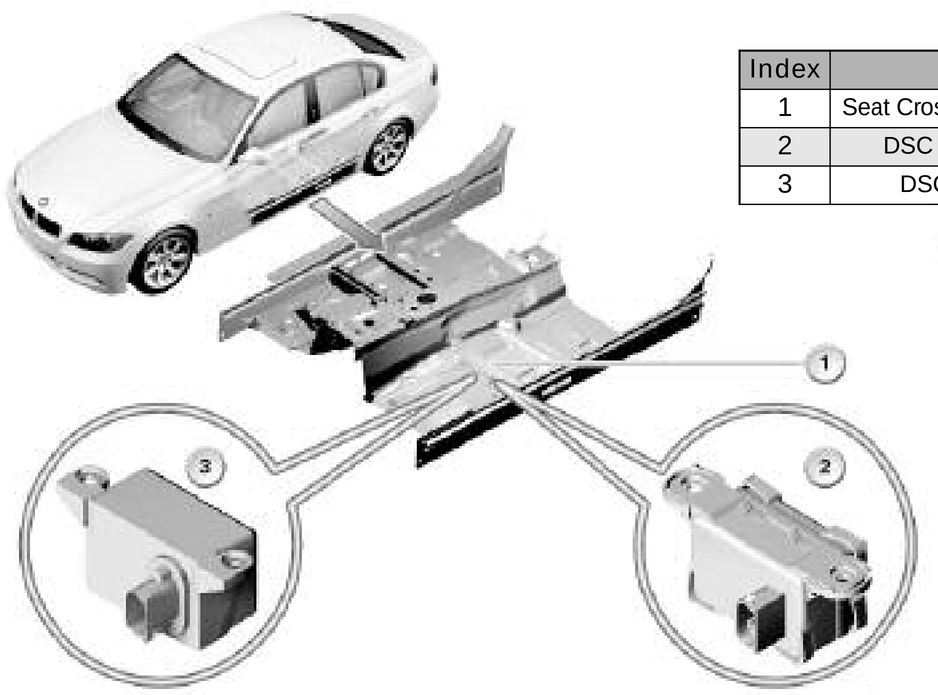
On this system the inlet valves for the wheel brakes and distribution valves are actuated in such a way that the flow rate is variably controlled via a PWM signal.

Wheel-Speed Sensors

Four active wheel-speed sensors measure the speed of the individual wheels. This type of sensor is also able to recognize the direction of wheel rotation.

DSC Sensor

The DSC sensor on vehicles equipped with active steering utilizes 2 yaw rate sensor elements to transmit redundant signals capturing the rate of yaw (rotation about the vertical axis) and lateral acceleration to the AFS module via the chassis CAN (F-CAN)



Index	Explanation
1	Seat Cross Member Driver's Side
2	DSC Sensor without AFS
3	DSC Sensor with AFS

DSC Module

The DSC module consists of the hydraulic module and the DSC control electronics.

All 5 brake pressure sensors are integrated into the valve block of the DSC module.

Note: The circuit board of the DSC control module also contains an integrated longitudinal-acceleration sensor which is used for the start assist function.

Steering-Angle Sensor

The steering angle sensor is located in the steering column switch cluster (SZL) and optically measures the angle of rotation of the steering wheel.

Signal path to the DSC control module: Steering column switch cluster -> F-CAN (looped through JBE) -> DSC control module

DTC Button

The DTC button is located in the center console between the central air vents and has three operating modes:

1. DSC operational (standard setting)
2. DTC operational (If DTC button is depressed once DSC switches Off)
3. DSC and DTC completely deactivated (If DTC button is depressed for extended period)

Signal path to the DSC control module: DTC button -> JBE -> PT-CAN -> DSC module

The instrument cluster receives the signal through the K-CAN.

Brake Fluid Level Switch

If the brake fluid level is too low, this will be detected (via a reed contact in the expansion tank) and an appropriate message is sent to the DSC control module.

DSC is deactivated if there is insufficient brake fluid.

Signal path to the instrument cluster: DSC module -> PT-CAN -> JBE -> K-CAN -> Instrument cluster

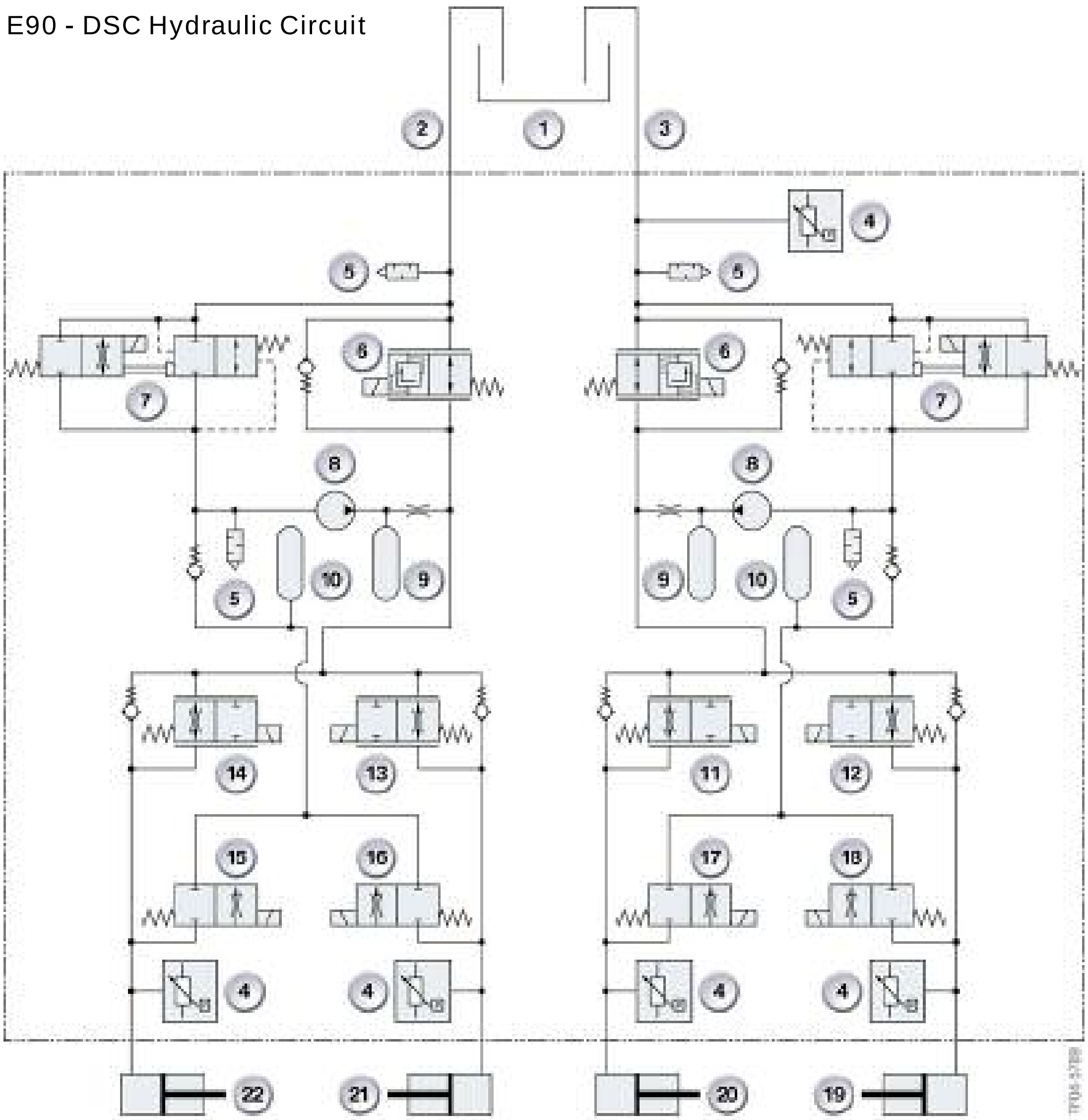
Brake Light Switch

Together with the signals from the brake pressure sensors, braking actions are recognized.

Parking Brake Warning Switch

DSC will recognize skidding that has been deliberately initiated by the driver and regulation will not take place, since a handbrake turn should remain technically possible.

E90 - DSC Hydraulic Circuit



Index	Explanation	Index	Explanation
1	Brake Fluid Expansion Tank	12	Inlet Valve (Analog), Right Front with Switching Orifice
2	Rear-axle Brake Circuit	13	Inlet Valve (Analog), Right Rear
3	Front-axle Brake Circuit	14	Inlet Valve (Analog), Left Rear
4	Pressure Sensor, Push Rod Circuit	15	Outlet Valve, Left Rear
5	Pulsation Damper	16	Outlet Valve, Right Rear
6	Isolating Valve	17	Outlet Valve, Left Front
7	Electric Changeover Valve	18	Outlet Valve, Right Front
8	Self-Priming Return Pump	19	Wheel Brake, Right Front
9	Damper Chamber	20	Wheel Brake, Left Front
10	Accumulator Chamber	21	Wheel Brake, Right Rear
11	Inlet Valve (Analog), Left Front with Switching Orifice	22	Wheel Brake, Left Rear

Sensor Information

Sensor	Functional principal	Manufacturer
Active wheel-speed sensors*	Magneto-resistive principle	Teves
Steering angle sensor (LWS) in steering column switch cluster (SZL)	Optoelectronic	
Yaw rate sensor	Twin tuning fork principle	Teves
Lateral-acceleration sensor	Capacitive principle	Teves
Longitudinal-acceleration sensor**	Integrated in DSC control module	
5 pressure sensors	Integrated in hydraulic block	
Brake light switch	Hall principle	
Brake-fluid level switch	Reed contact switch	

* Wheel-speed sensors with grey shield = MK60E5 with direction-of rotation detection (the braking response when traveling in reverse is different then it is for vehicle traveling forwards, output to navigation system, EGS etc.)

* Wheel-speed sensors with black shield = MK60psi (Used on E87 Non U.S. Model) does not have direction of rotation capability

** For the start assist function

General Overview

The DSC system is a Driving Stabilization System and offers the following advantages:

- DSC optimizes driving stability when pulling away, accelerating, braking and coasting.
- DSC recognizes and reduces unstable driving conditions such as understeering or oversteering.
- DSC improves traction, especially with Dynamic Traction Control (DTC)

Within the limitations of the laws of physics, DSC helps to keep the vehicle on a safe course.

To do this, DSC must know the following parameters regarding the vehicles driving dynamics:

- Yaw rate as a measure of rotary movement of the vehicle around the vertical axis
- Lateral acceleration
- Road speed
- Longitudinal acceleration

In addition, the driver's intentions are recognized via input from:

- Steering angle sensor
- Brake pressure sensor
- Throttle setting/ accelerator pedal position

The values are used to establish the actual condition in which the vehicle is currently moving and to compare these values with those calculated by the DSC control module. If the actual values differ from the calculated values, DSC is activated and initiates brake actions or engine control functions.

Advantages:

The DSC system counters all dynamically unstable driving conditions within the physical limitations dictated by the laws of physics, to enhance driving comfort and safety.

Anti-lock Braking System(ABS)

ABS prevents the wheels from locking when the brakes are applied.

Advantage: Optimum utilization of road surface friction - the vehicle remains stable and steerable.

Brake pressure is regulated at all wheels to ensure that each wheel runs with optimum slip. When this happens, slip is controlled so that the maximum possible braking and lateral stability forces can be transmitted.

Electronic Brake Force Distribution (EBV)

EBV is a component of ABS and controls the brake force distribution between the front and rear wheels.

Advantage: Regardless of the vehicles load state, the best possible braking distance is achieved while maintaining driving stability.

Modern vehicles have relatively large brakes on the rear axle to shorten braking distances. To prevent the rear wheels from being overbraked in certain driving situations, EBV permanently monitors wheel slip and controls rear axle slip independent of the front axle.

Cornering Brake Control (CBC)

CBC is an extension of ABS. CBC enhances driving stability if the brakes are applied when cornering.

Advantage: If the brakes are applied in a corner, optimum brake force distribution ensures tracking stability.

When cornering, even very light braking can shift the axle-load distribution to the left or right so that driving stability is impaired. If required, CBC generates a stabilizing load moment when the brakes are applied lightly outside the ABS intervention range.

Automatic Stability Control (ASC)

ASC prevents the wheels from spinning when the vehicle is accelerating.

Advantage: Improved traction and vehicle stability.

If one of the wheels of the drive axle is on a high-grip surface and the other is on a slippery surface, the wheel tending to skid is braked.

ASC also intervenes in the engine control (to reduce the ignition angle, injection quantity, throttle valve setting) in order to reduce/inhibit vehicle acceleration in the event of wheel slip.

Dynamic Traction Control (DTC)

The functions of the DTC correspond to those of DSC with a slightly modified regulating characteristics. DTC is activated by deactivating DSC (DTC button depressed). DTC intervenes in the braking actions to imitate the function of a conventional differential lock.

Advantage: DTC allows better traction.

Vehicle stabilization intervention (e.g. reduced power output) is delayed slightly, compared to DSC, which enhances traction with a slight loss of driving stability.

This function offers a compromise between driving stability and traction, especially when accelerating and/or driving uphill on a loose surface or snow-covered road surface (surface friction requiring more slip).

DSC provides a high degree of driving stability with adequate traction, however DTC offers better traction with a slight reduction in stability. Therefore, the deactivation of DSC should be reserved for emergencies (driving in deep snow, for example).

Engine Drag Torque Control (MSR)

If the vehicle is operated in low gear while coasting downhill or if is the vehicle is suddenly shifted into a lower gear, the drive wheel may be slowed down by the engine braking effect to rapidly which can result in an unstable operating condition, resulting in the drive wheels locking up.

Engine Drag Torque Control (MSR) provides protection against locking of the drive wheels.

Advantage: The drive wheels retain their lateral stability in overrun mode.

The wheel speed sensors tell MSR as soon as the wheels are about to lock. MSR then briefly reduces the engine's drag torque by opening the throttle slightly.

Dynamic Brake Control (DBC)

DBC supports the driver in emergency braking situations. It does this by automatically increasing braking pressure if the brake pedal is not depressed with sufficient force.

Advantage: Shortest possible braking distances in emergency braking situations by achieving ABS regulation on all four wheels.

The brake pedal is frequently not depressed strongly enough in emergency braking situations. The ABS feedback control range is not reached (or not on all 4 wheels).

RPA: Tire Defect Indicator

RPA is not a driving dynamic function.

DSC uses the Run Flat Indicator (RPA) to monitor the tire pressure throughout the journey.

The RPA records the wheel speeds using the wheel-speed sensors of the Dynamic Stability Control (DSC). The RPA compares the speeds of the individual wheels with the average speed. In this way the RPA is able to detect a loss of tire pressure.

The RPA detects a drop in pressure below about 30% ± 10% of the initial value. The RPA indicator and warning light indicates a drop in tire pressure.

The RPA will indicate this after just a short distance, as a rule after a few minutes, from a certain minimum speed (e.g. 25 km/h) up to the permissible top speed.

Initialization is started manually. Then (after a journey has started), initialization runs automatically. In other words, the circumference of individual tires are recorded and evaluated.

The initialization phase lasts approx. 5 to 15 minutes for the individual speed ranges.

CBS: Condition Based Service

CBS is not a driving dynamic function.

Condition Based Service, as the name suggests, is a means of ensuring that the car is serviced as and when necessary. CBS comprises various maintenance operations, e.g. engine oil, spark plugs and brake pads.

The remaining distance for the front and back brake pads are calculated separately in the DSC control module.

When making the calculation, the condition of the brake pad wear sensors is taken into account (reference point at 6 mm and 4 mm).

Important !!! Refer to ST056 Chassis Dynamics for more detailed information regarding the operation of the DSC System Functions.

Workshop Exercise - Dynamic Stability Control

Check procedure for initialization of steering angle sensor using diagnostic equipment (DISplus/GT1).

Classroom Exercise - Review Questions

1. What new function are introduced with the MK60E5 system and what do they do?

2. On what other vehicle will MK60E5 be used?

3. What is the purpose of the 5 pressure sensors?

4. What is Yaw Moment Compensation? What option must the vehicle have installed?

5. What is different with the DSC button??

6. What is different with the wheel speed sensors used on the E90?